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Investigating design: A comparison of manifest and latent approaches

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Abstract

This paper contributes to the on-going focus on improving design research methods, by exploring and synthesising two key interrelated research approaches – manifest and latent. These approaches are widely used individually in design research, however, this paper represents the first work bringing them together and explicitly investigating their complementarity in the design domain. This is realised using an example artificial observation study. In addition to discussing underlying relationships between the approaches, this paper identifies key opportunities for improving design research methods by more explicitly combining both manifest and latent elements. Finally, a number of combinatory approaches are proposed based on a conceptual framework.

Keywords: Research methods, design research, design science, latent and manifest approaches

The designer has formed the focus of a significant amount of design research over the last decades (Cross, 2007, Frankenberger et al., 1998). In order to fully explore this focus researchers have adopted a wide range of perspectives, from the physical activities of designers (Robinson, 2010, Lindahl, 2006) to investigations of their cognitive processes (Kavakli and Gero, 2002, Dong, 2005); a result of which has been the adoption of both manifest (explicit) and latent (implicit) approaches. Despite this difference, manifest and latent approaches are fundamentally linked, and have been compared and integrated in a range of fields in order to improve both quantitative and qualitative research (Neuendorf, 2002, Hair et al., 1998, Mayring, 2000, Potter and Levine Donnerstein, 1999).

One example where the combination of these two perspectives has led to greater insight in the context of design is that of the on-going investigation of novice and expert designers. Consider, for example, the work of Ahmed et al. (2003) who highlight the differing mental processes used by experienced and novice designers. Here, a latent approach has been used to reason about what the recorded variables mean in the context of the design process used by the designers and thus differentiate them. In contrast, Cash et al. (2013) compare a number of manifest variables associated with design activity – revealing substantial similarity between expert and novice participants. These two works can be synthesised to give a significantly more nuanced understanding of the subject. For example, the baseline elements of the design activity (e.g. information exchange) are almost indistinguishable between experts and novices, yet significant differences remain in both the latent interpretation of a more sophisticated design process and the manifest metric of raw numbers of ideas. In other words, both approaches give complementary yet distinct information, combining to reveal new insight.

Manifest and latent approaches are well established – as exemplified above – and fundamentally and philosophical linked. However, there has been no specific discussion within design research of the relationship between them, or the possible benefits of their explicit synthesis and combination in the design research context. This is despite significant attention and success in other fields, such as in methodological research (Gray and Densten, 1998), and in applied clinical research (Graneheim and Lundman, 2004, Gray and Densten, 1998).

Based on this deficit this paper contributes directly to the on-going focus on exploring and improving design research methods (Cash et al. 2012, Dorst, 2008, Cross, 2007). This is realised by describing a conceptual framework for understanding the two approaches – manifest and latent – as complementary, based on an explicit comparative study in the design research domain. In addition to identifying and describing a framework for understanding the underlying relationships between the two approaches, this paper identifies key opportunities for improving design research methods by systematically combining both manifest and latent elements. Finally, the comparison enabled by this approach highlights a number of important areas for future research in the design field.

The next sections give an overview of manifest and latent approaches and describe a conceptual framework linking them (Section 1) before outlining the study and the specific approaches to be used in the comparison (Section 2). Finally, results are presented and discussed (Section 3) and implications and key areas for further research identified (Section 4).

1 Background and Comparative Framework

Key to the comparison proposed in this paper is differentiating between how manifest and latent approaches give insight into design and bringing them together in a common reference frame – allowing for their explicit synthesis. Despite their fundamental inter-relation, working definitions for predominantly manifest and latent approaches are described here, as this is the context in which they are typically encountered within the literature. Manifest approaches can be defined as ones focusing on explicit, objectively observable phenomena, where coder judgement is minimised and there is a direct relation between the observed data and the outcome of the approach. For example, a manifest approach might seek to characterise and group the features of a sketch or the physical characteristics of computer use based on their frequently appearing properties. Conversely, latent approaches focus on implicit abstract or theoretical constructs which are identified through one or more observable measures (Robson, 2002), and in turn interpreted through coder judgement (Potter and Levine Donnerstein, 1999). For example, a latent approach might seek to infer the internal cognitive processes of a designer based on observable phenomena, such as, sketching or computer use. Latent approaches focus on 'hypothesised and unobserved concepts that can only be approximated by observable or measured variables' (Hair et al., 1998, Neuendorf, 2002). This section introduces each type of approach in the context of design research (Sections 1.1 and 1.2) before bringing them together with respect to validity and reliability (Section 1.3), theoretical considerations (Section 1.4), and finally the proposed conceptual framework, synthesising extant theory (Sections 1.5).

1.1 Manifest Approaches

Manifest approaches focus on describing what is directly observable without assigning a meaning to it at the time of coding – essentially focusing on the first order value of the data. Although this might at first seem contrary to the normal research imperative it has a key role in grounded approaches where predefined understanding is not always possible or even desirable (Glaser and Strauss, 1967, Hanington, 2007). This can be illustrated in the design domain by, for example, Kim et al. (2012). Here Kim et al. use a generative study to identify abstract features that people associate with connectedness (e.g. intertwined elements in a logo – see example Figure 1) for the purposes of developing products that inspire social connectedness. In this context the internal mechanisms by which people associate abstract shape and social connectedness are not known. Therefore, a manifest approach is adopted to identify the abstract shapes generated by participants when asked to design logos representing connectedness. The manifest approach then allows common features to be identified via, for example, statistical analysis, without having to build on an understanding of the participants' cognitive process or significant interpretation of the data. This eliminates several sources of possible bias, removing the need for underlying constructs and reducing the influence of researcher interpretation.

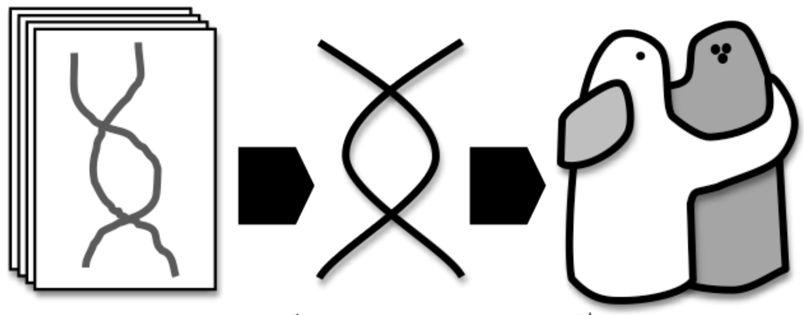

Figure 1: Illustration of a manifest approach based on the Kim et al. (2012) example.

Manifest approaches, where interpretation is limited, are a common feature of studies where prior theory is not available to drive the development of latent approaches. This plays a key role in the design domain where there is often a lack of generalizable theory (Tomiyama et al., 2009, Blessing and Chakrabarti, 2009). For example, Robinson (2010) uses a sophisticated, multi-layered manifest schema to capture designer's information behaviours. Here Robinson takes advantage of the objective nature of manifest approaches to list clearly understood features of designer process and behaviour, in relation to information, that can be identified based on their direct occurrence and observed properties, without relying on a deeper understanding of underlying phenomena. This allowed the schema developed by Robinson (2010) to be applied in industry – with the designers themselves recording the data – without the need for extensive training or the introduction of observational biases via assessing own behaviour. Another area where manifest approaches are common is in content analysis (Neuendorf, 2002). For example, Grierson (2013) uses such an approach for classifying information content in distributed design work – facilitating more detailed analysis. A final example in the design domain is that of engineering design knowledge. Here a grounded approach is often used in classifying information and knowledge with respect to the design process or specific technical components. An example of this type of approach is presented by Ahmed (2005), who uses technical features to classify design knowledge. As such, manifest approaches can also be used to support the development of grounded taxonomies such as the Design Ontology (Ahmed and Storga, 2009, Storga et al., 2010).

Despite this wide range of uses there is much that can only be investigated via latent approaches, particularly where pre-existing theory dictates implications for objective observations.

1.2 Latent Approaches

Latent approaches focus on interpretation of underlying theoretical constructs through observable elements within data at the time of coding – focusing on the implied value of the data via the judgement of the researcher. These approaches are often developed from underpinning theory in order to assign meaning to the observed phenomena – generally falling into the theory testing side of the larger research process (Eisenhardt and Graebner, 2007, Gorard and Cook, 2007). This is because latent approaches fundamentally utilise higher orders of interpretation, filtering the data through several layers of judgement, and, as such, require significant underlying theory to guide their interpretation. In practice, latent approaches can be split into two main categories, dependent on the purposes of the study to be completed (Potter and Levine Donnerstein, 1999). *Latent pattern* approaches consider that manifest and observable cues within data exist, and it is the meaning of these elements in relation to the underlying theory that are of interest for research. *Latent projective* approaches consider that it is the interpretation of meaning itself that is of interest, therefore generating the data set from the categorisation and judgements made by the coders. For example, a latent pattern approach may be chosen to code properties of an object such as value, based purely on visual estimation. Here, value is determined by coders through understanding of cues such as expensive materials or complex geometry (hence, underlying theory and the patterns extant in the observable cues). A latent projective approach may be chosen to code interpretation of aesthetic beauty of an object through its appearance. Here, while some link between underlying theory and observable cues may exist, the high level of coder interpretation reduces possibility for consistent and objective categorisation. Accordingly, such an approach would be more suitable for the study of cues that determine beauty, than it would as a method of robustly stating beauty of objects.

Both such approaches are used within the design research domain. For example, Atman et al. (1999) studied the design approaches of junior and senior engineering students completing a consistent task. Here, through the use of verbal protocols and recorded visual data, the manifest actions and statements of participants were assigned to abstract categories concerning the relevant design step, the information processed, the activity completed, and the object under consideration. This example of a largely latent pattern approach takes the manifest verbal protocol and actions of the participant and, through theory and validation, equates their underlying relationship as representing the design step (for example) at which the participant is working. Due to the varying context surrounding actions, such an interpretation is not possible through a manifest approach alone. For example, the appearance of a sketch can be indicative of the exploration or analysis of a design problem, or the generation of a design solution.

A typical example of the use of a latent projective approach is that of expert opinion for evaluation (such as, the consensual assessment technique (CAT), Amabile (1982)). Here it is assumed that the knowledge of experts represents a correct interpretation of the subject matter. Sarkar and Chakrabarti (2011) use the intuition of experts as one form of validation of their creativity evaluation method, based on the assumption that the intuition of experts forms an accurate judgement of the creativity of the products of interest. To do this they correlate their own metrics against the judgement of the experts, in essence, studying the categories that the experts intuitively employ in their assessment.

As such, a latent approach is a common feature of studies where prior theory exists to drive the analysis and the formation of the coding method. In cases where analysis is highly context dependent or highly complex, it is the interpretation of manifest cues that demonstrate the underlying meaning of the data. For example, Goel and Pirolli (1992) categorise design statements made by twelve experts during design protocols, according to a scheme devised from existing theory. Each statement is assigned through the inferred "aspects of design development" within, determined by manifest cues such as content and context. This then allows placement within such categories as problem-structuring statements and problem-solving statements, or according to design stage. Here, Goel and Pirolli take advantage of the latent data to make conclusions beyond those possible through the manifest cues alone, utilising the inferred understanding from highly contextual statements. Similarly, Lloyd and Scott (1994) categorised utterances of participants gathered through protocol analysis as being generative, deductive, or evaluative based on the content of each statement and existing literature. This allowed them to study the appearance and interplay of each type of statement through the design process, forming conclusions regarding the reasoning modes of the designers and the phases of the design process; neither of which could be determined directly from manifest cues. These examples serve to highlight a key feature of latent approaches, namely, that they are fundamentally linked to and either explicitly or implicitly build on manifest analysis elements in order to carry out the higher level latent analysis.

This is further illustrated by the role of latent approaches in the study of creativity in design. They are particularly relevant in this field due to the range and lack of consensus in definition (Chakrabarti, 2006) and the highly contextual and cognitive nature of its study (Hayes, 1989). As such, researchers frequently rely on latent determination of creative level or the factors that contribute towards it. However, these assessments build on a range of established manifest cues. For example, the coding of designer protocols to determine cognitive processes and the role they play within creative processes (Benami, 2002), the coding of creative level using distinct metrics (Torrance, 2008), or using expert opinion (Christiaans and Venselaar, 2005, Sarkar and Chakrabarti, 2011).

While latent approaches allow study of more abstract and contextual concepts within data, beyond the direct capabilities of manifest approaches, they require both increased development from existing theory and careful construction and use in order to maintain their reliability and validity. This is due to their greater remove from the original data and reliance on higher orders of interpretation.

1.3 Variance of Reliability and Validity in Manifest and Latent Approaches

Of particular importance when considering manifest and latent data approaches is the reliability and validity of the coding and analysis (Potter and Levine Donnerstein, 1999, Krippendorff, 1981, Neuendorf, 2002, Blessing and Chakrabarti, 2009). While these describe the forms of validity that must be created in all schemes, it is the balance between reliability and validity in manifest and latent approaches that is of particular interest in the context of this paper – as this is fundamentally related to the nature of the link between the approaches.

In a manifest approach, both reliability and validity can be generated through construction of categories and the rules by which data is separated. Each property that distinguishes an element of data as belonging to a category is evident by its own definition (such as the use of an information source e.g. Robinson (2010)), and, therefore the tightening of rules to differentiate between categories is sufficient to increase coding reliability.

As manifest approaches are often used for the purposes of developing theory, testing of validity should be unaffected by the coding process and should occur following analysis. In some cases, researchers will use a manifest approach to analyse more subjective matters; for example the Torrance Tests of Creative Thinking (TTCT) (Torrance, 2008), which code factors contributing to creativity through manifest marking of sketches. While these cases are likely to have higher reliability in coding due to the rigidity of their schema, it is vital that construct validity is tested prior to their use. In the case of the TTCT, for example, that the manifest markings coded are representative of the category to which they are assigned, and also that the categories are representative of creative level as a whole. This can prove very complex, and is debatable even for widely-used schema such as the TTCT (Kim, 2006). When construct validity cannot be assured in this manner, and no consistent pattern between manifest evidence and the more abstract subject of interest exists, there is a need for greater interpretation and thus a latent approach becomes appropriate.

In latent approaches, meaning must be inferred from data due to the abstract nature of coded concepts, a lack of direct known connection between manifest, observable cues and the phenomena of interest (latent *pattern*), or when it is the judgement of coders that forms the data itself (latent *projective*). In all these cases care must be taken in balancing the relationship between reliability and validity (Potter and Levine Donnerstein, 1999). This is particularly important as each order of interpretation either explicitly or implicitly builds on preceding layers of interpretation (which can themselves be either manifest or latent). As such, the potential sources of error increase significantly as the order of interpretation increases. To tighten the rules used in these approaches would restrict the coding process by shifting it away from the interpretation of the coders, and towards the structures set by the coding schema. Unless backed by existing theory, such a process would reduce the validity of the coding process (and hence subsequent analysis) by preventing appropriate inference of meaning from data i.e. introducing error via each interpretation step. In this context, tightening the rules would instead force coders to categorise strictly by coding guidelines, thus becoming a manifest approach and inhibiting latent interpretation. In such a case, the coding becomes inherently invalid because there is insufficient scope to link observable cues within data to the phenomena of interest; thereby making the schema unrepresentative of the phenomena it purports to study. It is therefore vital when using a latent approach that the coding rules are developed to encourage judgement of the coders and inference from data (in order to maintain validity), while also demonstrating that the inferences analysed are reliably made by all coders, and are valid in terms of the over-arching subject of research.

It is important within any approach to test the inter-coder reliability of the scheme; ensuring that the same results are produced regardless of the researcher, particularly in cases where coding is reliant on judgement. To test inter-coder reliability a number of different measures can be used, such as, Cohen's kappa (Cohen, 1960), and Krippendorff's alpha (Hayes and Krippendorff, 2007), although percentage agreement should not be used (Hayes and Krippendorff, 2007). Typically, a result in excess of 0.80 is acceptable as indicator of reliability (Neuendorf, 2002), although 0.70 can be taken for exploratory research (Blessing and Chakrabarti, 2009, Klenke, 2008).

1.4 Role of Theory in Determination of Appropriate Approach

A common theme, and distinguishing feature, in the above descriptions, is the role of underlying theory in determining an approach that is appropriate to the research. Manifest approaches here can take two roles. First, in the case where little theory exists, it is the place of the approach to allow the development of theory through analysis. Second, in the case where sufficient theory exists, the approach is suitable to directly, validly and reliably associate observed cues with theoretical concepts (such as occurs in the TTCT tests (Torrance, 2008)). In contrast to the manifest approach, latent approaches follow a theoretical stance where manifest cues are used to elucidate higher orders of meaning. Here, while theory describing the phenomena must exist for the coding schema to be formed, due to complexity and variability in the purpose or interpretation of the observed cues a manifest approach is not appropriate. Given these differing roles, when selecting an approach to follow, a major consideration is the existence of theory (or lack thereof) describing the phenomena of interest and its connection to the data to be gathered.

Depending on the purpose of the research, some scope for the implementation of each approach exists in many given research subjects. For example, in the study of designer behaviour, there is a wide body of research on which to build, resulting in much underlying theory from which to form manifest coding schemes (when subject of study is appropriate), or alternatively to inform latent analysis linking data to more abstract concepts. Therefore, by focusing on designer behaviour as the phenomena of interest, both manifest and latent approaches can be considered in relation to a common reference frame.

Exploring this further, consider the following manifest and latent examples. In works such as that of Robinson (2010), cues in the actual actions of engineers form the basis for manifest analysis of behaviour. Here, the higher level concept of behaviour is inferred from the combination of individual instances of activity. These approaches require each activity and its categorisation to have a proven, consistent and reliable association with the identified behaviours, such as that of technical work being a part of problem solving behaviour. The use of a manifest approach is, however, only possible when theory is suitably developed for confidence to exist in the relation between observed cue and behaviour. When there is ambiguity in what the observed cue represents it is not possible to assume related behaviours, only the occurrence of the cue itself. The use of a manifest approach for the study of designer behaviour (when based on known theory) allows appropriate and valuable findings with a high reliability and validity within the bounds of well-accepted theory, but with ambiguity at higher orders of interpretation.

In contrast, the study of designer creativity (also within the field of designer behaviour) often follows a latent research approach. This is primarily due to the inherent complexity, variation and lack of consensus on some elements in the study of designer creativity. As such, it is difficult to form direct and robust connections between data and theory. Therefore, expert judgement is often used as the assessment lens in this context, either for identifying more or less creative solutions (latent *pattern*, see Kruger and Cross (2006)), or for studying the categories factoring into the identification of creativity itself (latent *projective*, see Sarkar and Chakrabarti (2011)). Conversely, the formation of definitions for creative output (original, of appropriate quality, and unobvious (Howard et al., 2008)) gives scope for following a more manifest approach when identifying more or less creative solutions (examples of steps towards such methods can be found in Shah et al. (2003), Sarkar and Chakrabarti (2011)). Thus, assuming that creative output is the result of designer behaviour and can be assessed through discrete metrics, this forms a method of study using a more manifest approach. However, this has the disadvantage of lacking clarity when assessing the validity of the results.

Further, the unit of analysis, or granularity, is another consideration. Depending the phenomena of interest there is scope for a varying level of granularity in the data to be analysed. For example, the use of individual words, chunks, sentences, or paragraphs as discrete entities to be coded. Here, the unit of analysis should be chosen such that it is both appropriate for the subject being studied and the desired understanding. The relationship to manifest and latent approaches again considers the role of known theory. Where data at a high level of granularity is shown to be consistently representative of the phenomena of interest (i.e. a specific word indicating negativity in a team) a manifest approach may prove applicable. Where this is not the case, a lower level of granularity may be required to either provide sufficient data for manifest interpretation (i.e. words in combination consistently indicating negativity), or sufficient manifest cues for latent interpretation (i.e. several words that in combination are interpreted as indicating negative sentiment). Thus at a high level of granularity, there is potentially insufficient data for a latent interpretation to be reliably and validly made. Specifically, latent analysis is built upon the interpretation of manifest cues, and so when manifest cues cannot be formed at a higher level of detail, latent analysis cannot occur. This is further explored in Section 1.5, discussing the orders of interpretation inherent in each approach. In practice, a suitable level of granularity should be selected based on the existence of extant theory and the level of detail at which appropriate results can be produced.

The selection of approach in research is therefore not a clear distinction between appropriate or inappropriate research designs. Given a detailed backing in extant theory, a manifest approach may be suitable for a wide variety of analyses, including those that might traditionally be thought of as reliant on latent study. For example, taking the view that the creative product can be studied through the appearance of categories such as originality and quality alone, a manifest study is viable.

However, taking the view that creativity is a more complex subject reliant on, for example, social interpretation and group consensus (Csikszentmihalyi, 1999, Boden, 1994), purely manifest analysis cannot be used with high confidence. In application, the selection of approach for any research requires consideration of the extant theory within a field and the contrasting perspectives upon the phenomena of interest. When theory exists and can be employed with confidence in the case of the specific study, a valid and reliable manifest approach can potentially be employed. Where theory is more ambiguous, the phenomena of interest is complex or variable, or perspective upon it is split within the field, a more latent approach is likely more appropriate.

There is then a dependence on the willingness of the researcher to partially sacrifice validity or reliability (depending on theory, desired granularity and the approach followed, see Section 1.3). As such, understanding and managing the relationship between these factors and the spectrum of possible approaches is critical to research rigour, validity and generalisability.

1.5 Conceptual Framework

In conclusion, although both approaches rely on it, interpretation differs in terms of depth, level of abstraction and potential for generating new perspectives. Therefore, in order to compare them it is first necessary to consider in what frame these perspectives can be meaningfully brought together and the subsequent learning related to the design research domain. In this context, focus lies on the fundamental characteristics of each type of approach. As such, the common reference frame used to bring the approaches together was defined as: their relationship to the original data and the order of interpretation at which they primarily operate.

Figure 2 graphically represents the main types of approach, the order of interpretation at which they exist, and the continuous progression from data to approach, via which all the approaches are fundamentally related. In order to explore the implications of the conceptual framework it is necessary to discuss two concepts: the order of interpretation, and how the approaches are built up.

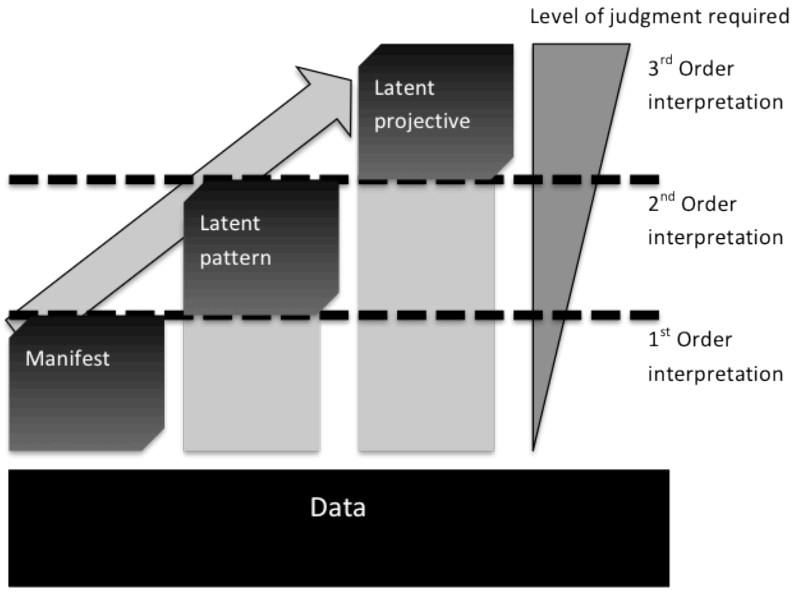

Figure 2: Conceptual framework linking manifest and latent approaches

First consider the order of interpretation as a key differentiating feature. In the preceding review manifest approaches were described in terms of their focus on 'first order' interpretation of data, while latent approaches focus on higher orders of interpretation. This can be described in terms of three distinct levels as follows:

- ***First order interpretation*** focuses on the innate characteristics of the data, judgement is minimised due to the rule-based assessment linked directly to data. For example, the categorisation of different sources of information used during a design task into groups, such as, 'internet' or 'textbook'.
- ***Second order interpretation*** focuses on using judgements by the coder to identify patterns in the 1st order or raw data, and subsequently assign a meaning to this based on extant theory. For example, a coder might judge that there is a pattern where a designer repeatedly consults a particular internet source and then a text book, and that this supports a particular feature of theory X.
- ***Third order interpretation*** focuses on analysing the decisions underlying 2nd order judgements. For example, a researcher might judge that the decision by a coder to associate the pattern of 'internet to textbook' as supportive of theory X rather than an alternative explanation implies deeper processes underpinning the judgement.

Thus as each approach focuses on sequentially higher orders of interpretation they fundamentally build on and are linked to the preceding levels; although the approaches can be characterised and utilised independently, they are related via the interlinked judgements at each order of interpretation. This often results in the lower orders of interpretation being used implicitly by higher latent approaches. Here the lower order analyses are established by theory or simply considered precursors to the actual analysis, thus forming part of the coding schema rather than generating data, and are left unreported beyond initial statements of validity. Further, due to the constructive nature of this framework (i.e. each approach building on aspects of those underneath) there is significant potential for the build-up of bias or other analytical error. At a higher order of interpretation there is a higher requirement for robust association between observed cues and the constructs they purport to measure. As a result there is also a higher potential for inappropriate assumptions to introduce error in data analysis, and hence reduce validity in the results. This is highlighted by the differing validity assessments and theoretical prerequisites for each approach, which must either explicitly or implicitly account for the error introduced by moving through the various orders of interpretation.

Building on this understanding and the conceptual framework two key implications can be drawn with regards to research methodology in design research. First, there are important issues associated with the various approaches in terms of application, the type of insight generated, reliability and validity. Second, due to their related nature there are significant possibilities for combining approaches to support improved research methods. In order to fully explore these implications and generate meaningful insights a comparative study is used – outlined in the next section.

2 Methodology

This paper uses an observational study based around an artificial task as the basis for bringing the manifest and latent approaches together in the context of design research. An artificial task was selected as this allowed for a robust comparison of the approaches and for divergence over the various design stages to be considered. In this study, the task required the design of a small-scale electro-mechanical device for mounting and manoeuvring a camera when attached to an unmanned drone or balloon. The underlying focus of the study was on designer behaviour, which acted as a unifying field towards which both approaches could contribute. As discussed in Section 1.4, the role of theory within the field sets some limits on the approaches that can be employed in such a study. Specifically these limits depend on the phenomena being investigated, the theoretical stance of the researcher, and the desired areas of compromise in validity, reliability and generalizability.

For the purposes of the comparison two independent and established schemas were adopted (manifest – Section 2.2 – and latent – Section 2.3) which have both been explored in prior works. Developing the comparative schemas from previously validated works allows this paper to focus on synthesising the approaches via the conceptual framework rather than attempting to develop and justify a wholly new approach for each. Further, by developing a pre-existing schema this work serves to demonstrate the potential to extend and further explore the features of the design process investigated by the original authors, effectively further developing that dataset and independently validating it in this new context – a partial replication so to speak. Not only is replication in different contexts a key aspect of developing rigour in research (Neuman, 1997, Flick, 2009), and design in particular (Dyba and Dingsoyr, 2008), the explicit comparison of an existing work to other types of analysis approach allows for new areas of research to be identified and more fully explored – a key contribution of this type of comparative analysis.

Building on existing schemas allows this work to focus on developing an in depth comparison of the manifest and latent approaches whilst maximising applicability to the design research community. As such, this section goes on to summarise the basic method used to conduct the study before outlining the two coding approaches to be used as the basis for the analysis detailed in Section 3.

2.1 The Study

The study consisted of an artificial design task separated into four phases, which moved participants through two divergent/convergent iterations (Design-Council, 2006) – resulting in two periods of individual design work (information seeking and information seeking/design development) suitable for comparison. The prescribed process was as follows: *individual information seeking > group brainstorming > individual information seeking/design development > group design review*. This four-phase process was developed to mimic in brief the engineering design process seen in industry (Cash et al. 2013), and as recorded by other researchers (Hales, 1986, Ulrich and Eppinger, 2012).

Population

The population was randomly selected from a group of 40 final year Masters level engineering students at a UK university. All the students were selected from a generic product design course. This ensured that they were familiar with the design process and would be able to undertake all the prescribed tasks. Further, this selection ensured that factors such as educational background, experience and level of training were similar. Twelve students were selected from this group and split randomly into four teams of three.

A sample size of twelve was selected, as it was sufficient to allow preliminary non-parametric statistics to be applied to the comparison of the approaches. The use of within group statistics was considered appropriate as there is no clear underlying theory to define a hypothesis driven comparison of latent and manifest schemas and, as such, a larger scale sampling design could not be specified appropriately. Instead a smaller descriptive study allowed for multiple perspectives to be taken in exploring and synthesising the two approaches. In this context two approaches can be used, the Pearson's correlation followed by T-test or the Spearman test of correlation and it's associated significance test. Further, in order to establish which is appropriate for a given dataset both need to be applied. Where Pearson's is greater than the Spearman's value the correlation is linear and thus the Spearman's test is not appropriate. In this case both techniques were applied and it was found that the data consistently gave a higher Pearson's value indicating linearity in the correlation. As such, the Pearson's correlation and associated T-test were considered appropriate here. The terms and related tests used throughout the analysis are: Pearson's correlation coefficient (r) to determine correlation *strength*, and a two-tailed students t-test to assess correlation *significance*. Strength and significance will henceforth be used to denote these features. Both tests were selected for compatibility with the give sample size.

Method

The key parts used for the comparison between the approaches were the individual periods (giving the best sample size whilst also providing a basis for analysing the manifest and latent approaches in relation to the conceptual framework (Figure 2)). In terms of the observation method used as the basis of the coding and comparative analysis three distinct perspectives were adopted. First, the participants' individual workspace was observed using a standard high definition webcam. Second, each participant was issued with a desktop PC, which recorded all screen activity through the Panopto recording software (Panopto, 2012) (synchronised with the webcam) allowing for the monitoring of software use and other activities. Finally, the participants' logbook activity was recorded in real time using LiveScribe pens (LiveScribe, 2011). Combining these three perspectives gave comprehensive coverage of all the participants' activity during the sessions as well as covering the use of other materials such as textbooks or catalogues available in the workspace. With the comprehensive recording so formed it was possible to effectively apply both manifest and latent coding approaches to the full dataset.

In order to narrow the scope of the comparison it is necessary to focus on one element of design behaviour. In this respect one aspect stands out as particularly apt for this type of analysis given the conceptual framework and the design research context. Namely, information acquisition commonly referred to as information seeking in the design domain (Aurisicchio et al., 2010, Kwasitsu, 2004). Not only does this aspect of design work play a key role in individual design activity (the focus of this comparison) (Reed et al., 2011, King et al., 1994, Robinson, 2010) it builds on a well-established body of work – both manifest and latent – in the design field. In this sense information seeking provides the ideal focus for a comparison of manifest and latent approaches as it combines relevance to the design domain whilst also being grounded in substantive theory – allowing findings from the comparison to be generalised to the wider design context. While not the sole purpose of either approach used in this study and reported here, both required the coding of information seeking at the core of their process, and thus provided a highly suitable pair of approaches for comparison.

In this area a small core of key works stand out as potential foundations for the development of the two coding schemas. For the manifest approach Robinson (2010) is considered, while for the latent approach Klein (2000), Stokes (2001) and Gero (2000) are used as the basis for the development of the final schema. These are explored in more detail in Sections 2.2 and 2.3.

2.2 Manifest Coding

As noted in Section 2, an established schema was adopted for the purposes of the comparison and integrating with existing design research. The manifest coding schema used in this study was based on the work of Robinson (2010). In the context of this study, the manifest codes used focused on the direct information seeking aspects of Robinson's schema (2010). This narrowing of scope was used to improve comparability with the latent schema.

The codes used are outlined in Table 1. For the purposes of this study 'finding source' was classified as including search engine, search box, and other sites or services offering an index of other specific websites while 'finding within source' included all sites with information relevant to the task, which were not a listing or indexing other sites.

Table 1: Manifest information seeking variables

Code	Definition and measures
Find source	Searching for information relating to where specific product information is available This is measured as time (s) and number of instances
Find within source	Searching within a specific website for information related to the product This is measured as time (s) and number of instances

In practice, data was coded in two separate passes, each of which occurred immediately subsequent to the last. These passes consisted of: high-level separation – information seeking v. other activity, and then low-level separation of finding source and finding within source (Table 1). The initial coding of the combined information seeking variables at a course level is useful as it allows for an overall characterisation of the design work undertaken. As such, more focused analysis can occur while remaining linked to the wider context of the work undertaken. Detail of reliability and validity within this process is discussed in Section 3 in conjunction with the comparison of the two schemas.

With respect to the conceptual framework (Section 1.5), the manifest approach focuses on first order interpretation. Through the elements directly observable in the data each code is both defined and identified. These are then directly coded as a representation of the designers' activity without further interpretation by the coder. This method of coding is both reliable and maintains a high validity, within the given scope, through the use of categories that are evident by their own definition (Section 1.3). However, this does not imply wider validity when higher orders of interpretation are introduced. Therefore, the key feature of this scheme is the categorization of the observable actions at the 1st order level. As such, validity can be specifically assessed for this scheme by correlation of the results against other 1st order analyses of information seeking activity.

2.3 Latent Coding

As discussed in detail in other work (Snider et al., 2013a) and presented in summary here, the latent coding scheme was developed through existing theory for the purpose of analysing designer behaviour during the engineering design process, particularly that which is creative. Building on distinctions drawn within knowledge-based theories of design (Klein, 2000, Stokes, 2001), and differing forms of creative design (Gero, 2000, Dym, 1994), the scheme separates individual tasks into either the development of information or of design application (defined below). Each task is segmented using manifest entities present in the data (identified through type of content created by the participant), as occurs within the MOKA methodology (Stokes, 2001). Using such observable cues within the data, the coder then interprets the more abstract concept of type of task being completed; thereby following a latent *pattern* approach. The schema rules identify each basic task type through the different combinations of entities present, and whether they form an input or output to the tasks, but rely on coder interpretation to identify each combination within data and those entities that are assigned to input or output roles – see Figure 3 for an example of generic task decomposition.

> *Information* – concerned with the identification and development of information relevant to the design, and resources for use within the design process and design output.
>
> *Application* – concerned with the development of the design output itself (either virtually or physically), and hence the actual use of present information and design resource.

Each of these task types can then be completed in one of two different ways, dependent solely on the manifest entities that form the task input and output:

> *Single* – in which the designer either a) uses information resources as a basis to produce a more detailed version of the same (*information* type), or b) uses a preliminary version of the design output as basis to form a more detailed version of the same (*application* type).

Switching – in which the designer either a) uses information or design resources to increase the development of the design output directly (*application* type), or b) uses the current state of the design output as a subject of analysis, to increase the information and design resource present (*information* type).

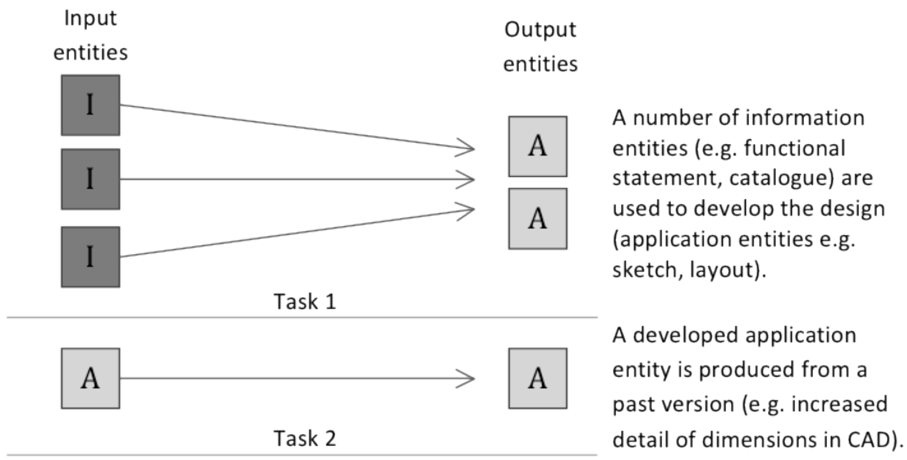

Figure 3: Two example tasks from the latent schema, requiring coder interpretation

This scheme also provides a means for identifying other features of the design process and designer behaviour, such as design stage or the identification of creative behaviour. Design stage is defined according to commonly used definitions (Howard et al., 2008, Gero, 1990), here described in Table 2. Evidence of creative behaviour is judged through the term expansion, representing the active introduction of new variables, information, resources and design iterations by the designer, beyond those that would be followed within a well-defined schema. Such an approach has many parallels in literature (Gero, 2000, Dym, 1994, Guilford, 1956, Cropley, 2006), and is discussed in more depth in referenced work (Snider et al., 2013a). As with all elements of the latent schema, the coder judges each of these categories based on the manifest entities present in the data.

Table 2: Definition of designs stages used within the latent approach

Design Stage	Activity Definition
Analysis	Determine the required and desired functions of the system, for it to complete its purpose.
Concept	Conceive the system functions in detail through preliminary description of system behaviour.
Embodiment	Design detailed system behaviour through preliminary description of system structure.
Detail	Design and finalise system structure, and all other concerned aspects.

In practice, data was coded using the scheme in three separate passes, each of which occurred immediately subsequent to the last. Following preparation of data for coding, these passes consisted of: task separation, design stage (according to Table 2), and determination of task type. The last of these in itself involved three sub-steps: first – identify individual entities in the data, second – identify basic task boundaries and input/output, third – code the appearance of creative behaviour.

Detail of reliability and validity within this process is discussed in Section 3 in conjunction with the comparison of the two schemas.

With respect to the conceptual framework (Section 1.5), this latent pattern approach considers second order interpretation. Through the observable cues in the data allowed by the use of entities from the MOKA coding scheme, and the understanding of creative theory developed as part of the underlying research, the coder is provided with the means to distinguish patterns in the data. These are then interpreted as individual designer "tasks", where the combination of these tasks subsequently forms the interpretation of designer behaviour. This method of coding prevents a drop in validity associated with over-constrictive rules (Section 1.3), while providing a consistent grounding from which reliability of analysis can be ensured. Therefore, the key features of this scheme are the interpretation of the observed entities, their relationship to the underlying theory on which the scheme is built, and their relationship to the phenomena of interest (the study of creative behaviour). Thus validity can be specifically assessed for this scheme by correlation of the results against the Kirton Adaption-Innovation scale (Kirton, 1976). This is an external measure of creative style, with significant correlations reported and discussed in other work (Snider et al., 2013a, Snider et al., 2013b). As such, it is possible to build confidence in the lower order characteristics on which the interpretation of this scheme occurs, minimising the potential associated drop in validity.

2.4 The Process of Study

As each coding process was independent, two coders could perform both concurrently, each of whom had extensive experience using their respective schema. Following the coding and further analysis procedures given below, results were collated and contrasted as discussed in Section 3. In particular, correlations were identified according to the Pearson Rank Correlation, with significance tested by a two-tailed students t-test.

The coding of the manifest data took place in two steps. First, data was synchronised between each source – logbook data, video recording and screen capture. Second, the data was coded according to the scheme and practical points summarised in Section 2.2. This process involved two sub steps: high-level separation, and low-level coding of source. Following the coding the results were compared to a number of extant studies on information seeking activity (Holscher and Strube, 2000, Kellar et al., 2007, Robinson, 2010).

Coding following the latent approach occurred through two individual steps. First, data was again synchronised between each source. To aid subsequent coding, this process also involved segmentation of the data on a minute-by-minute basis through description of the activity of the participant. While actual coding is not temporally bound, rather focusing on the cumulative occurrence of different types of task, this granularity ensured detailed study of all the actions of each participant. Second, the data was coded according to the scheme summarised in Section 2.3. Following coding, the results were validated through correlation against the Kirton Adaption-Innovation scale (Kirton, 1976), as noted above.

2.5 Phenomena of Interest

As noted in Section 2.1 these schemas, and hence the coding processes, were designed with respect to behaviour in the engineering design process. Specifically, although there is some difference in focus, both are designed to identify individual tasks (in the process of an engineer or group of engineers), which are then used as the base unit of analysis. There is hence significant overlap in the phenomena of interest from each approach.

The primary difference between each, and the distinction that stimulated the use of different approaches, is in the desired research output and underlying theory, as discussed through the examples in Section 1.4. Here, the manifest approach was developed to study information seeking and was built on the well-established scheme and theory discussed by Robinson (2010). Thus this was rooted in studying the actions of engineers at an observed level, subsequently implying behaviour from observed cues. As a result, a manifest approach was appropriate. Key to its application is then the theoretical connection between the manifest actions of the engineers, and the underlying phenomena that these actions can be said to describe; which in turn imply findings through the analysis process.

The latent approach was also developed to study the behaviour of engineers through actions observed in their individual tasks, but with a particular focus on the identification of creativity. This occurred through the interpretation of abstract "types of task" to allow categorisation of every action into one of four groups, and subsequently allowed interpretation of the appearance of creative behaviour. As discussed in Section 1.4, creativity as a subject is able to claim only loose links between individual appearances in data and the underlying phenomena of interest due to a combination of complexity, ambiguity, and lack of consensus. As a result, at current levels of understanding, a latent approach utilising the interpretation of human observers is the most suitable research approach. However, implied here is one potential weakness of a latent approach. The requirement for interpretation precludes the ability of the judge to make multiple interpretations of identical occurrences, each of which may be valid by current understanding. For example, a moment of silence within a team protocol could potentially be interpreted as either a problem solving or interactional strategy. This underlines the importance, when using a latent approach, of validity of assumptions and the theory upon which interpretation is based. As such, ambiguity of interpretation must be accounted for whenever possible to ensure that results can be used with confidence, are valid, and are reliable (Section 1.3).

In conclusion, difference exists in the underlying theory regarding the phenomena of interest, and the resulting orders of interpretation that are required to produce a valid and reliable scheme. However, the common focus on identification of tasks and their use as the base unit of analysis gives a level of direct complementarity between these two schema and two research approaches. There is then a comparison to be made between the learnings and capability that each provides as a result of the approach followed, as will be presented in the following sections.

3 Results and Discussion

This section outlines a comparison of the results from the two approaches with respect to the example study described in Section 2. These are subsequently used as the basis for identifying general implications and bringing the two approaches together in Section 4 based on the conceptual framework outlined in Section 1.5. Throughout, Phase 1 and 3 are used respectively to refer to the study phases *individual information seeking* and *individual information seeking/design development.* Results are provided in summary only, as their purpose is to illustrate the comparison of the outputs from the two approaches and not in the presentation of discrete findings from the individual studies in-and-of themselves.

First, consider the activity undertaken by the designers and how the two schemas give distinct yet complementary insight. Here, the latent scheme examines the fundamental types of task completed by the designers. This highlights a distinct shift from an information task focus to an application task focus as the designer progresses through the phases of design (Phase 1: 90.9% info-type, 9.10% app-type; Phase 3: 20.9% info-type, 79.1% app-type). This is mirrored in the manifest scheme, which shows a shift in the amount of information seeking activity (finding source and finding within source) from Phase 1 (avg. total = 69.2%) to Phase 3 (avg. total = 21.2%). Further, the average ratio between finding source and finding within source changes from 0.46 (Phase 1) to 0.67 (Phase 3), suggesting a change in the way the two activities interact as the design stage changes. However, unlike the latent approach it is less immediately clear how these changes are linked to the wider theory of design activity. Thus both the latent and manifest approaches highlight the majority of activity in the early stages of the design process (Phase 1) as spent developing information for use within the design and identifying resources that may be used at a later point, while the later stages focus on making use of this information and resources in a more practical sense – reducing the amount of new information needed (reduced total time) and making the search activity significantly more targeted (increased ratio). In this way the two approaches can be seen to be mutually supportive while also giving individual insight.

This assessment is further confirmed by an examination of the later design stages (Phase 3). Here, the latent approach elucidates a heightened focus on the design itself, with the designers producing iterative designs at increasing levels of detail whilst also integrating the requirements defined at the outset of the phase, and those identified during Phase 1. Here again, the latent approach offers an immediate explanation in the context of moving through the design process stages, while the manifest approach offers a means for confirmation and expanding understanding. This results in the following conclusion supported by both approaches. As the focus shifts significantly towards application of the design during the design process, there is a steep drop in information tasks. The designer has the information that they think is required to produce the design solution, and as they progress the design they move from a blanket search for information to a more targeted approach, only occasionally completing information tasks for the purpose of clarification and to address new considerations that appear during the iterative design process. The combination of the two approaches here allows for a more nuanced description of the finding and lends more credence to its assertion via the triangulation of the two different perspectives.

Despite these complementary elements the two approaches are significantly different in their practical application and the type of insight they give. This is illustrated by the contrast in what each approach can directly say about the designers' activity. In this context, a particular strength of the latent scheme is its ability to identify and analyse the individual behaviours of the designers, based on the manifest entities within the data. This is closely related to the fact that the latent approach can be more directly tied to theory in comparison to the manifest approach. As such, the latent scheme allows for the identification of particular areas of focus of designers throughout the process via the types of task completed, patterns of activity and individual differences. In contrast, the manifest scheme allows a detailed breakdown of the designers' activity with respect to objective criteria but does not give immediate directions for the interpretation of this data. Further, as highlighted in the background section, clear differences were also observed in the practical application of the approaches, particularly with respect to speed and reliability. Specifically, the latent schema required a ratio of circa 8 hours of coding for every 1 hour of video, whilst the manifest schema achieved a ratio of 1 to 1. Differences were also evident in the testing of inter-coder reliability, with the latent schema requiring one week of training and testing to achieve the same, minimum value reached by the manifest schema in one hour (Cohen's Kappa = 0.8). For the latent scheme this one week training process is a short but suitable time scale to produce valid results (Milne and Adler, 1999). However, training of multiple coders for a latent schema will often occur over a longer time period, even months, during which iterative and careful re-development of coding rules will increase reliability, while ensuring that validity is maintained (Krippendorff, 1981).

The comparison of the two approaches described in this paper highlights an important aspect of using combined or multiple perspective approaches – the generation of new and distinct insight beyond that given by a single approach. In this case creative behaviour was a key area where this was exemplified. In a collective sense, the latent scheme showed switching tasks maintaining a higher creative proportion within more detailed design stages. While at an individual designer level switching tasks often remain creative at later stages (e.g. Phase 3, embodiment and detail design stage tasks) there is a very high level of variation between designers, with some completing a majority of switching tasks, and some completing none at all (avg. switching proportion completed by designer 31.6%; range 0% to 75%; S.D. 23.9%). In addition, and as forms a primary finding in other work (Snider et al., 2013a), there is a significant preference for designers to individually favour creative tasks that are either of the application type or information type within later design stages. This distinct variation between designers highlights the importance of considering the designer as playing the central role in the design process, where their individual characteristics significantly influence the type of output. This finding is supported and extended by the distribution of activity seen in the manifest approach. Here both Phases 1 and 3 showed a wide range of results. For example, finding within source had a range of 54.2% and 30.5% and a standard deviation of 16.9% and 9.7% in Phases 1 and 3 respectively. As such, it can be seen that even when completing identical briefs under identical conditions, the process followed by each designer is individual, demonstrating differing styles of creativity and differing design activities over the course of the design process. That this is evident in both approaches underlines and reinforces the validity of the insight.

Finally, Table 3 highlights the specific correlations between the approaches. The focus of this work is on highlighting the complementarity between the approaches and, as such, detailed raw data is not included here. Instead consider that despite the fundamental differences of the approaches they both link back to underlying features of the designers' behaviour and activity. For example, information-type tasks as described by the latent approach involve the identification of new information for use as a resource within the design process. Conversely application-type tasks involve the application of those resources to form the design solution. As a result, the medium correlation between information-type tasks and both "Finding Source" and "Finding within Source" shows complementarity of results, and therefore approaches. Findings can also be implied from these correlations – therefore by the combination of each approach. Take, for example, the correlation of "Finding Source" with creative tasks in Phase 3, which is not present for "Finding within Source". This indicates that designers who more frequently search for new sources of information are more often creative than those who more frequently search for information within sources. This presents a logical and interesting finding – a characteristic of more creative designers may be their searching for different sources of information, whilst a characteristic of less creative designers may be in their acceptance of the sources already known, and the finding of the relevant information within. This finding would not be possible using either scheme alone, and thus shows the benefit of triangulation between results from each approach. As such, this highlights the key role of combined latent/manifest approaches for triangulation and validation. Also, as the correlation is not perfect i.e. there are some Phases where no correlation is observed, Table 3 serves to emphasise the fact that each approach is distinct and adds to the wider understanding without simply being a repetition. Although analysis of these correlations may provide interesting findings in-and-of themselves, in the context of this paper their purpose is solely to illustrate the added value and complementarity of using both manifest and latent approaches.

Table 3: Significant ($p < 0.05$) correlations between the two approaches

	Finding Source		Finding within Source		Ratio	
Phase	1	3	1	3	1	3
Application	-	-0.49	-	-0.58	-	-
Information	-	0.49	-	0.58	-	-
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Single	0.54	-	-	-	-	-
Switching	-0.54	-	-	-	-	-
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Creative	-	0.51	-0.56	-	0.53	-
Non-creative	-	-0.51	0.56	-	-0.53	-

4 Implications for Design Research

Based on the example study described in Section 3 as well as the review outlined in Section 1 it is possible to identify key features of the two approaches as well as their associated strengths and weaknesses. This section presents important considerations of both manifest and latent approaches as highlighted through the presented study, results and discussion, before bringing them together to suggest pragmatic means for combining the two approaches in practice, in order to maximise their benefits (see Section 4.2).

4.1 Pragmatic Considerations

Based on the theoretical considerations discussed in Section 1 and illustrated via the study in Section 3, key pragmatic considerations can be synthesised for design research. Here each area discussed throughout the text is distilled with respect to the two approaches. In particular this section builds on the results highlighting the differences in the application of the approaches to the example design case. Specifically: application, insight, reliability, and validity are considered.

Application and Insight

Latent – More directly linked to theory and thus more appropriate for theory testing or in the context of a previously established understanding of the phenomena under investigation. This link to theory gives the researcher the means for generating in depth understanding of the subject but limits the scope of investigation to the prior theory or constructs used. The latent theory based nature of the approach makes it ideal for generating in depth understanding of a constrained phenomena. However, as it is resource intensive and theoretically constrained, it is less suitable for analysing large amounts of data over time or in terms of number of variables.

Manifest – No need to be directly linked to theory and can be used in the context of generative or grounded approaches. The fact that prior theory is not required allows the data to lead to many different perspectives and be reanalysed with respect to a range of possible constructs/research questions. The manifest nature of the approach also means that it is ideal for generating large amounts of data across a wide scope both temporally and in terms of variables.

Reliability

Latent – Much more difficult to develop reliability without sacrificing validity through over constraint of the coding rule set. Inter-coder reliability requires extensive training, testing and iteration in order to achieve agreement.

Manifest – Highly reliable and easy to manipulate through extended rule definition and the identification of objective coding criteria. Little training required and inter-coder reliability usually established quickly.

Validity

Latent – Although significantly more time consuming, successful application can be directly related to theory giving high levels of validity. However, this can be in conflict with reliability as more in-depth understanding and interpretation is required of the coder.

Manifest – Completely dependant on the rules used for the coding and, as such, there is significant scope for misinterpretation of manifest data resulting in poor validity. However, as reliability is high, there is potential for this to be countered by the inclusion of more variables, and investigation across a wider temporal scope and in terms the measures used.

4.2 Combining the Two Approaches

Given the strengths and weaknesses highlighted above and the discussion in Section 3 it is apparent that combining the approaches can offer significant advantages. As such, we propose four key ways for combining the two approaches in order to maximise their respective strengths in an overall combined research approach. The four combined approaches are depicted in Figure 4 and described below. It is intended that these complement extant research on combined methods and have been developed specifically to be complementary and applicable in parallel to the work of Hanson et al. (2005) on combining qualitative and quantitative approaches. It should be noted that despite surface similarity between the ways for combining qualitative and quantitative approaches, latent and manifest can be used in either context and, as such, each combination is distinct from Hanson et al's work due to the fundamental differences in the strengths/weaknesses of latent/manifest and qualitative/quantitative approaches.

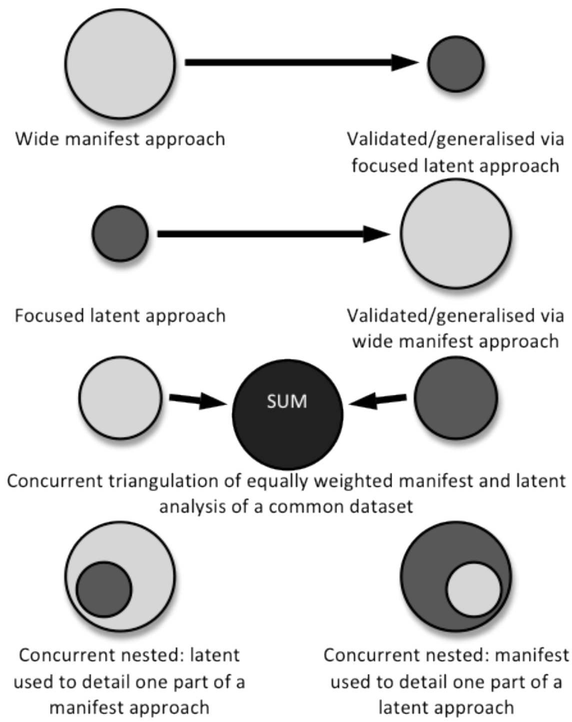

Figure 4: Four ways of combining latent and manifest approaches in order to maximise their combination

Combined approach 1: Manifest > Latent. This utilises the reliability and speed of the manifest approach to generate a wide scope dataset in order to contextualise the subsequent in-depth latent investigation. This maximises the generalisability of the latent findings by tying them to the wider manifest study. Further, by conducting the initial manifest investigation the latent elements can be more effectively targeted within the extant dataset while the manifest data can be used to check the validity of the construct used as the basis of the latent approach. As such, this approach can be employed effectively even when there is no significant extant theory.

The utility of this combination is highlighted by the difference in speed, and reliability achieved by the two approaches in the example study. Here the manifest approach offered a rapid and reliable schema while the latent offered more insight at the cost of increased time, reliability, and validity requirements. As such, these results highlight the possible role of the manifest approach in narrowing the scope of the investigation and providing a reliable baseline for facilitating further work or replication. Specifically, the manifest approach detailed finding source as key activity that, building on the correlations between the approaches (Table 3), could have been used to inform the application of the latent approach.

For example a manifest work sampling or longitudinal observational approach could be used to generate a grounded dataset giving a long-term view of design in practice. This could then be extended and detailed by the addition of a smaller scale latent approach e.g. laboratory studies of key phenomena, which are used to increase the depth of understanding whilst retaining its link to the wider context via the earlier, manifest work. An example of this type of approach can be found in the recent work of Cash et al. (2013).

Combined approach 2: Latent > Manifest. This uses existing theory to target and conduct and in-depth latent investigation which is then subsequently tied to the wider context and validated more broadly using a wider scope manifest study targeting a number of key objective variables. This again aims to maximise the generalisability of the findings by bringing together both depth and breadth. Using the manifest approach second allows the variables to be more effectively targeted and tied to theory from the latent study – allowing for a wider scope in terms of time and width. Further, as this approach builds on an initial latent investigation it is most effective for theory testing or the examination and subsequent generalisation and validation of pre-existing constructs.

Although not explicitly explored in the case, the correlations highlighted in Table 3 and discussed in Section 3 illustrate the potential for this type of implementation. As such, this approach could subsequently be used to significantly expand the study scope without the additional issues associated with expanding the latent schema.

For example a detailed laboratory study could be used to generate an in-depth understanding of a phenomena via pre-existing theoretical hypotheses and to subsequently identify key manifest indicators. These indicators could then form the basis of a much wider manifest study of industrial practice across a number of contexts and over time, in order to establish the generalisability of the latent findings and identify how it impacts actual practice whilst avoiding data overload by effectively targeting the manifest metrics. Examples of this type of approach are typical in cases where latent schemas have been developed to a point where detailed understanding of theory allows manifest means to be used. For example, the latent interpretation of the TTCT test (Torrance, 2008) is realised through a detailed manifest schema, built through careful latent analysis over many studies. Similarly, Goel and Pirolli (1992) use manifest means to provide detail to latent characteristics developed through theory.

Combined approach 3: Concurrent triangulation. This utilises independently developed manifest and latent approaches to give two different perspectives on a single dataset. This gives a broader insight into the data whilst ensuring that important elements are not missed by the focused latent approach. Further, by combining the two distinct perspectives greater validity can be assigned to results where agreement is observed between the two approaches – the key benefit of triangulation.

This approach formed the major focus of the results discussed in this work and is illustrated by the significantly more nuanced insights elucidated with respect to the study. In particular, consider the complementary results with regard to creative behaviour. Here, variation and individuality in creative style is mirrored in the distribution of the manifest activities. It is possible to extend the scope of investigation beyond that of each individual approach and also generate new results, such as detailing the development of information during the early stages of the design process.

For example, a single dataset can be examined using multiple independent schemas, both latent and manifest, in order to generate new insight into key situations or periods where theory predicts critical activity to take place. This type of approach is exemplified by the repeated reanalysis of core datasets as described by McDonnell and Lloyd (2009), and is highlighted in the combined results and discussion within this work.

Combined approach 4: Concurrent nested. Similar to Approaches 1 and 2 this utilises either manifest or latent elements to detail a specific part of a wider dataset in order to check validity or extend the scope of the analysis. However, distinct from Approaches 1 and 2 the nested approach allows for partial triangulation between the approaches on a single dataset and also allows for them to be guided by each other in parallel – potentially reducing development time and allowing for more targeted development.

Although not explicitly addressed in this study, the discussions outlined in the conceptual framework (Section 1.5) and throughout the results highlight the potential utility of such an approach. In particular, the use of the latent approach to explore detailed areas also identified by the manifest study illustrate how this combination could be used to iteratively narrow the scope of study while extending each approach in turn.

For example consider an approach where both a wider manifest study e.g. a survey study, is executed in parallel to a series of more in depth latent study e.g. detailed interviews, in order to give a overview, whilst also giving specific insight into a number of key areas. This approach is somewhat mirrored in studies that utilise think-aloud protocols, in which a participant will complete a task while verbalising their thought processes throughout (Gero and Tang, 2001). In these cases, the manifest cues of the actions of the participant are supplemented by verbal data, which is often interpreted by the researcher to provide significant additional depth, context and understanding for specific aspects of the phenomena of interest.

5 Conclusions

This paper contributes to the on-going focus on improving design research methods. Specifically, the use of latent and manifest research approaches has been explored in this context. A review of the literature revealed the importance and key underpinnings of these approaches for current design research but highlighted two key deficits in this field. First, there has been no direct examination of the strengths, weaknesses and complementarity of the two types of approach – making their combination and maximisation difficult. Second, there is no explicit understanding of how they are fundamentally linked or can be combined in order to improve research standards – a key feature identified in related fields. This paper has addressed both of these gaps by identifying, describing and unifying the types of approach in the design research context. This was realised via an example study highlighting the key methodological features and tradeoffs associated with each approach. Further, four key combinatory approaches have been proposed in order to allow design researchers to more effectively utilise latent and manifest perspectives to improve research rigour, validity and generalisability. This contributes to, and extends, the work on using combined methods in the design research context, but also serves to highlight the on-going need for further investigation of the tradeoffs associated with such approaches and for reflection on the use and maximisation of effective methods in design research.

Acknowledgements

Text here – see acknowledgements attachment

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